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Application of Feldspar Sand in Non-Autoclaved Foam Concrete Technology

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Abstract

The aim of this study is to determine the possibility of producing non-autoclaved foam concrete of grade M35 with a density of 900 kg/m³. A distinctive feature of this development is the testing of twin samples from the same batch: some were steamed in a chamber at 90 °C under normal atmospheric pressure, while others were autoclaved at a pressure of 8 bar and a temperature of 170 °C. It was established that ordinary natural feldspar sands with a fineness modulus ranging from 1.43 to 2.45, containing quartz below the standard-regulated levels, can be used in the production of non-autoclaved foam concrete. It is not possible to obtain non-autoclaved D900 foam concrete of grade M35 strength using only cement, sand, and foaming agent. To achieve the specified strength, it is necessary to use coarse sand with a fineness modulus (FM) greater than 3, subjected to short-term grinding to reduce the FM to recommended values, and to additionally introduce sol-gel liquid glass. The novelty lies in the experimental confirmation of the features of strength formation in cellular concrete under both non-autoclaved and autoclaved curing conditions. Comparative tests showed that high strength in cellular concrete is achieved only when a chemical bond forms between the products of cement hydrolysis and hydration with quartz sand grains—conditions made possible through autoclaving.

Keywords: Autoclave; Non-Autoclave; Foam Concrete; Feldspar Sand; Quartz Sand; Sound Insulation.

1. Introduction

One of the topical issues in modern frame construction is the installation of interior, but especially inter-apartment, partitions. In addition to strength, the materials of partitions are subject to sound insulation requirements. These materials require qualified workers, and the masonry process itself is characterized by low productivity. In the practice of modern construction, the use of panels, in particular those made of polystyrene concrete, 60 cm wide, as a rule, 2.8-3.2 m long, and 10 cm thick, has been worked out. The latter is a prerequisite, since after the construction of the building frame, any crane operations inside the building become impossible. Polystyrene concrete panels are a three-layer structure in which asbestos sheets are glued to polystyrene concrete on both sides to protect it from fire. It seems that it is unsafe to have such panels inside the apartment, both from sanitary standards and in the event of a fire.

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A promising option for the installation of partitions is the use of panels made of cellular concrete, which is a non-combustible, environmentally friendly material. According to our previous studies, the best combination of the mass of the material and its sound insulation is provided at the density of cellular concrete equal to 900-1000 kg/m³ [1]. Despite the obvious advantages of cellular concrete panels, their industrial production is restrained for a number of objective reasons.

Autoclaved aerated concretes can be directly used for the manufacture of panels due to their properties (strength, low shrinkage). But due to the low loading capacity and the need to reinforce the panels, which excludes the processes of cutting both the array itself into separate panels and cutting grooves on each panel, the autoclave production technology seems to be technically and economically inexpedient. An alternative option is the technology for obtaining panels from non-autoclaved foam concrete using cassette technology. In this case, these shortcomings are eliminated, including the "tongue-and-groove" system, which is formed directly in the process of forming panels.

However, according to a number of researchers, non-autoclaved foam concrete, even with a density of 800-1000 kg/m³, is characterized by insufficient strength [2-15]. Thus, according to Morgun [6] and Zhdanok et al. [13], D800 foam concrete has a compressive strength of 1.8 MPa; according to Granik [3], 1.1-2.9 MPa with a density of 700-1000 kg/m³; and according to Ukhova [4], 3.2 MPa with a density of 900 kg/m³. According to the results of tests by the authors of foam concrete blocks of various manufacturers in Almaty in the accredited laboratory of the Scientific Research Institute of Building Materials (Niistrom), the following results were obtained: The density of foam concrete is 800-900 kg/m³, and the compressive strength after 28 days of hardening is 1.2-1.8 MPa (with the value of 3.21 MPa normalized by GOST 21520-89), and shrinkage is 3.2 mm/m [16].

Nevertheless, due to the potentially high prospects of the technology of non-autoclaved foam concrete, the interest in this potentially progressive material does not decrease in universities and scientific institutions of various countries. Research is being carried out on the production of foam concrete of various densities and various functional purposes: from ultra-light foam concrete for thermal insulation to structural foam concrete used for the manufacture of load-bearing structures [17-33]. Analysis of these data shows that increased strength is achieved through a set of measures, including grinding of cement and aggregate, as well as the introduction of additives. However, in this case, it follows from the economic calculation that the material becomes uncompetitive with autoclaved aerated concrete.

In general, it is not clear from the analysis of literature sources whether it is possible to obtain M35 foam concrete at a density of 900 kg/m³ using a simple technology, using only cement, sand, and a foam concentrate. At the same time, the grain, but especially the mineralogical composition of the sand, in particular the quartz content in it, is of particular interest. GOST 25485-2019, which corresponds to the European standard EN 771-4-2003, directly states that for the manufacture of non-autoclaved cellular concrete, it is necessary to use quartz sand [34]. In quartz sands, according to GOST 31359-2007 [35], quartz should be at least 85%. Thus, it follows that if raw materials that meet the standards are used, then the production of cellular concrete with the required strength must be guaranteed.

In this work, the task was to determine the possibility of obtaining non-autoclaved foam concrete with a compressive strength of at least 3.5 MPa at a density of 900 kg/m³ based on natural sands, including the use of quartz sand. For the purity of the experiments, twin samples were formed from one batch, and at the same time some of the samples were steamed in a steaming chamber at atmospheric pressure, while the other part of the samples was steamed in an autoclave at an overpressure of 8 bar.

2. Methods and Objects

Experimental studies were carried out in the accredited laboratory of the Limited Liability Partnership "Research Institute of Building Materials and Design". The physical and mechanical properties of Portland cement, sand, and foam concrete samples were determined in accordance with current standards [33-38]. Sand grinding was carried out in a laboratory ball mill. The foam was prepared in a propeller mixer; the foam concrete mixture was prepared in a laboratory mixer of the German company "Testing". Steaming of the samples was carried out in a laboratory steaming chamber in accordance with the recommendations of SN 277-80 [39] in the mode of 1.5 + 8 + 1.5 hours at an isothermal holding temperature of 90°C, and autoclave treatment in a laboratory autoclave of the German company "Testing" according to the mode of 0.7 + 3 + 9 + 2 + 1 h at a pressure of 8 bar (see Figures 1 to 3). The samples were dried in the SNOL dryer. The test was carried out on the press of the company "Testing".

(a) (b)

Figure 1. Laboratory ball mill (a) and foam apparatus (b)

Figure 2. Mixer from the German company “TESTING” with a capacity of 2 liters and a laboratory steam chamber

(a)

(b)

(c)

Figure 3. Laboratory autoclave from the company "TESTING" (a); drying cabinet SNOL (b); and press from the German company "TESTING" (c)

2.1. Raw Materials

As raw materials, Portland cement of the M500 grade, Volsky quartz sand, natural sands with a particle size modulus of 1.86 and 3.15, a protein foaming concentrate "Biofoam" of Russian production were used, the characteristics of which are presented in Tables 1 to 3 and Figures 4 and 5.

Table 1. Physical and mechanical properties of Portland cement M500 of Bukhtarma cement plant

Physical and mechanical properties						
Residue on sieve 008 (%)	Normal density (%)	Setting time. H-min		Strength after 28 days of hardening. MPa. At		Compressive strength after steam curing. MPa
		Start	Start	Bending	Compression	
0.8	28	2-45	3-20	7.5	52.8	41.1

Table 2. Chemical and mineralogical composition of Portland cement M500 of the Bukhtarma cement plant

Oxide content. %						Content of essential minerals			
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	C_3S	C_2S	C_3A	C_4AF
20.85	5.62	4.22	63.52	1.53	2.09	56.29	16.62	7.28	13.14

Table 3. Granulometric composition of quartz Volsk, natural (feldspar) sand with Mk = 1.86 and sand with Mk = 3.15.

Sand	Partial residues. %. on sieves with a hole diameter of mm					
	2.5	1.25	0.63	0.315	0.16	Less than 0.16
quartz*	-	3.3	81.0	15.4	0.3	-
natural**. Mk = 1.86	0.05	0.98	25.07	41.33	22.79	9.78
natural ***. Mk = 3.15	20.6	16.7	25.1	33.1	4.0	0.5

*SiO_2 content – 98.7%; **SiO_2 content – 37%; ***SiO_2 content – 55%.

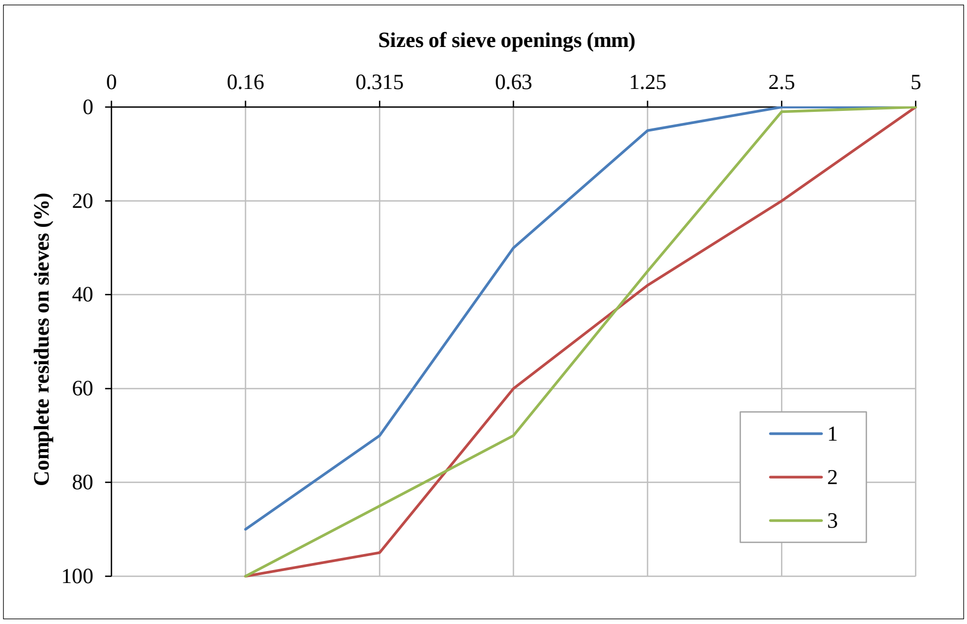


Figure 4. Screening curve of natural sands with a fineness modulus of 1.86 (1) and 3.15 (2) and quartz polyfractional sand with a fineness modulus of 2.91 (3)

The sand contains three phases: albite (40%), quartz (37%) and microcline (23%). Albite and microcline are feldspars.

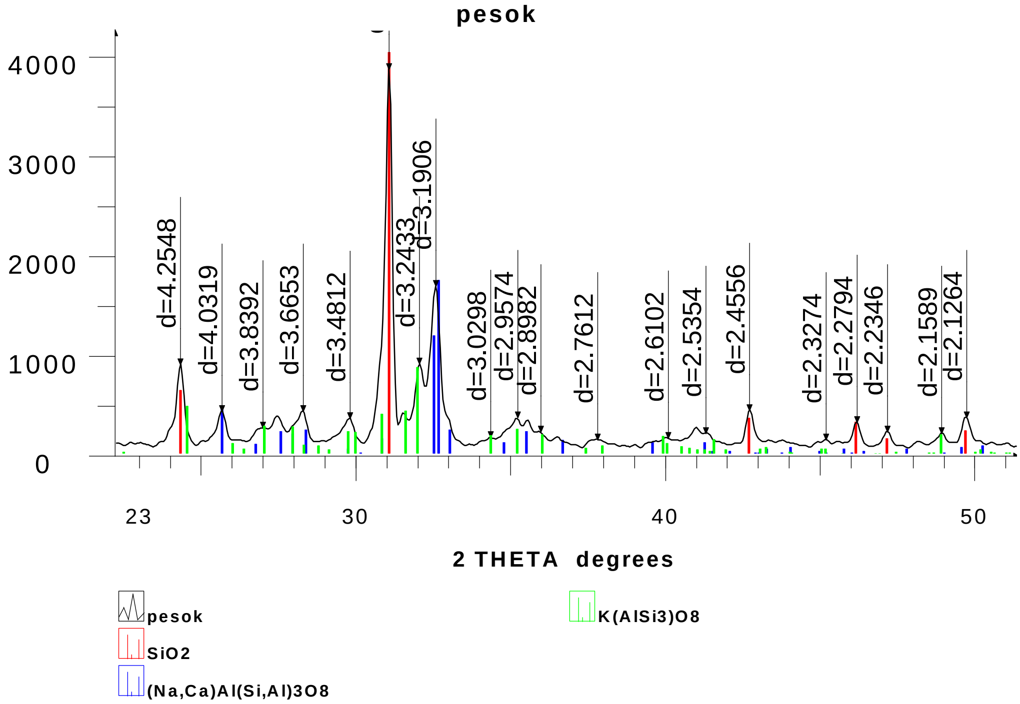


Figure 5. X-ray diffraction pattern of natural sand with Mk = 1.86

3. Results

The first stage of the experimental studies included determining the effect of fine natural sand with Mk = 1.86 on the compressive strength of foam concrete with a density of 900 kg/m^3. The sand was used both in its original state and after grinding for 1, 2, and 4 hours. The batch was prepared based on obtaining 2 liters of foam concrete mixture. The samples were molded in two standard sizes (cubes 7.07 × 7.07 × 7.07 cm and cylinders with a diameter of 4.8 cm, also 4.8 cm high), which was due to the capacity of the autoclave. In the autoclave, only cylindrical samples underwent heat treatment, in the steaming chamber - both cylindrical samples and cube samples.

The material consumption per 1 m^3 of foam concrete was:

- Portland cement M500 D0 – 415 kg,
- Sand – 415 kg,
- Water – 250 l,
- Foaming agent solution 2.5% concentration – 35 l.

The density of the resulting foam was 70 g/l, which ensured an increase in the volume of the foaming agent solution by 14.2 times. The molded twin samples, after preliminary holding, were subjected to heat treatment in a steam chamber and an autoclave according to the recommended SN 277-80 [39]. After heat treatment, the samples were held in the laboratory for 1 day, after which they were dried at 105 °C until they reached a constant mass. After cooling, the density of the samples was determined, then they were tested for compressive strength.

The first stage of the experimental studies included determining the effect of sand dispersion with different SiO2 content on compressive strength after heat treatment in a steam chamber and autoclave. For this purpose, fine river sand with Mk = 1.86 was initially subjected to milling for 1; 2 and 4 hours.

The results of the studies (Table 4, Figure 6) showed that grinding for 2 hours or more leads to a sharp decrease in the fineness modulus of sand (from 1.86–1.05 to 0.06–0.017, i.e. to the level of cement dispersion) and, at the same time, to a significant decrease in the strength of both autoclaved and non-autoclaved foam concrete (Figure 7). Thus, the strength of non-autoclaved foam concrete decreases from 2.5 to 1.4 MPa, and that of autoclaved foam concrete from 3.2 to 1.7 MPa.

Table 4. Granulometric composition of natural sand with Mk = 1.86, ground in a ball mill for 1-4 hours*

Sieve diameter. mm	2.5	1.25	0.63	0.315	0.16	Less than 0.16	Mk
Sieve residue. %. of original sand	0.05	0.98	25.07	41.33	22.79	9.78	1.86
Same. ground 1 h	0	0	1.07	37.48	27.62	33.83	1.05
Same. ground 2 h	0	0	0	18.31	23.09	58.60	0.06
Same. ground 4 h	0	0	0	0	17.33	82.67	0.017

* The specific surface area of crushed sand was, cm2/g: 1 h – 2350; 2 h – 3100; 4 h – 4200.

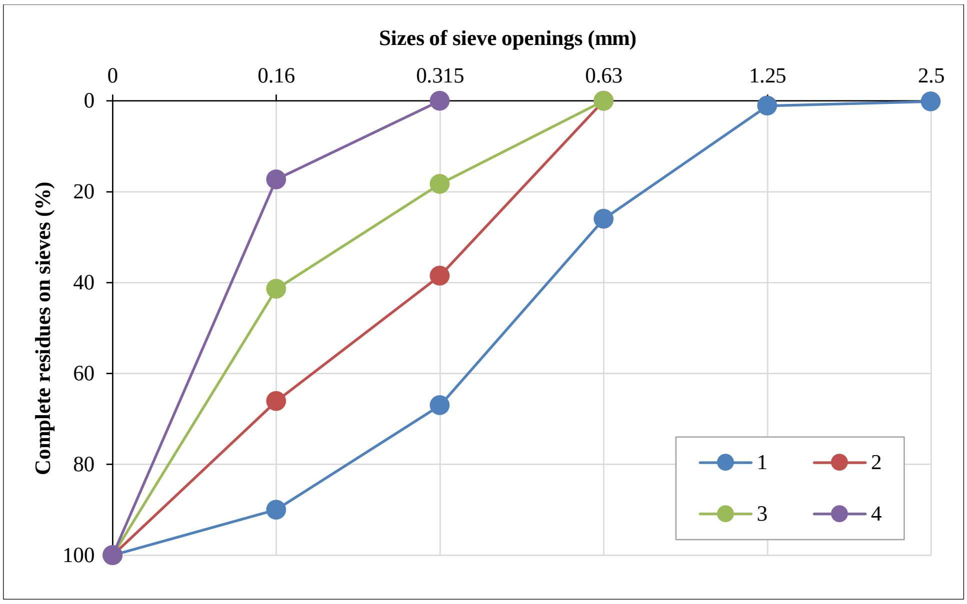


Figure 6. Screening curve of crushed natural sands with Мк = 1.86, Grinding duration, h: 1 – 0; 2 – 1; 3 – 2; 4 – 4.

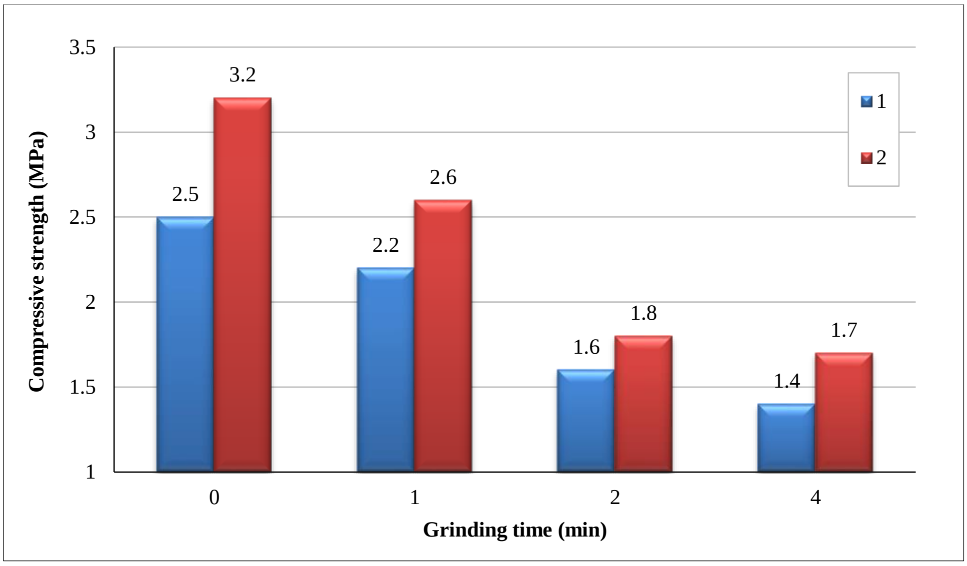


Figure 7. Effect of the duration of grinding natural sand with Mk = 1.86 on the compressive strength of foam concrete with a density of 900 kg/m^3, 1 – after steaming; 2 – after autoclave treatment

It should be noted here that, in essence, sand ground for 2 and 4 hours from the category of "fine aggregate" moved to the category of "filler", which led to deterioration of the foam concrete structure. Since the obtained filler does not have hydraulic activity, accordingly, the strength of cellular concrete decreases. In addition, the foam mass with filler from feldspar sand in a dispersed state, especially compositions No. 3 and 4, turned in consistency from a cast to a colloidal state due to the high dispersion of sand, especially its dust component. In this state, the system becomes immobile, including water, which hinders its access to cement particles.

As is known, colloidation is a system in which, due to high dispersion, solid particles (in this case, cement and sand) of nanometer or micron size are held in a suspended state due to Brownian motion or electrostatic repulsion between particles. Due to the presence of surfactants, surface tension forces act at the phase boundary (solid-liquid, solid-air, or air-liquid). Particles adsorb liquid and gas molecules, which stabilizes them in a dispersion medium. In our case, water loses fluidity and is also in a suspended state, which prevents the process of wetting and hydration of cement.

Thus, taking into account the results of testing fine sands, the milling time of coarse river sand was sharply reduced. For further testing, three lots of coarse river sand with Mk = 3.15 ground for 10, 20, and 30 minutes and two lots of quartz sand ground for 15 and 30 minutes were prepared. The granulometric compositions of natural and quartz sands, ground in a ball mill for different periods of time, determined by sieve analysis, are presented in Tables 5 and 6 and Figures 8 and 9.

Table 5. Granulometric composition of river sand with Mk = 3.15, ground in a ball mill for 10-30 min.

Sieve diameter (mm)	2.5	1.25	0.63	0.315	0.16	Less than 0.16	Mк
Sieve residue. %. of original sand	20.6	16.7	25.1	33.1	4.0	0.5	3.15
Same. ground 10 min	-	25.0	23.6	30.1	14.4	6.6	2.95
Same. ground 20 min	-	15.9	28.3	25.6	21.2	9.0	2.21
Same. ground 30 min	-	11.5	18.0	9.2	29.8	31.4	1.48

Table 6. Granulometric composition of quartz sand with Mk = 2.93, ground in a ball mill for 15 and 30 min

Sieve diameter (mm)	2.5	1.25	0.63	0.315	0.16	Less than 0.16	Mк
Sieve residue. %. of original sand	1.1	35.7	34.4	14.8	12.3	1.7	2.93
Same. ground 15 min	0.8	6.8	14.1	20.6	47.8	9.9	1.61
Same. ground 30 min	0.7	5.5	10.2	15.0	57.2	11.4	1.44

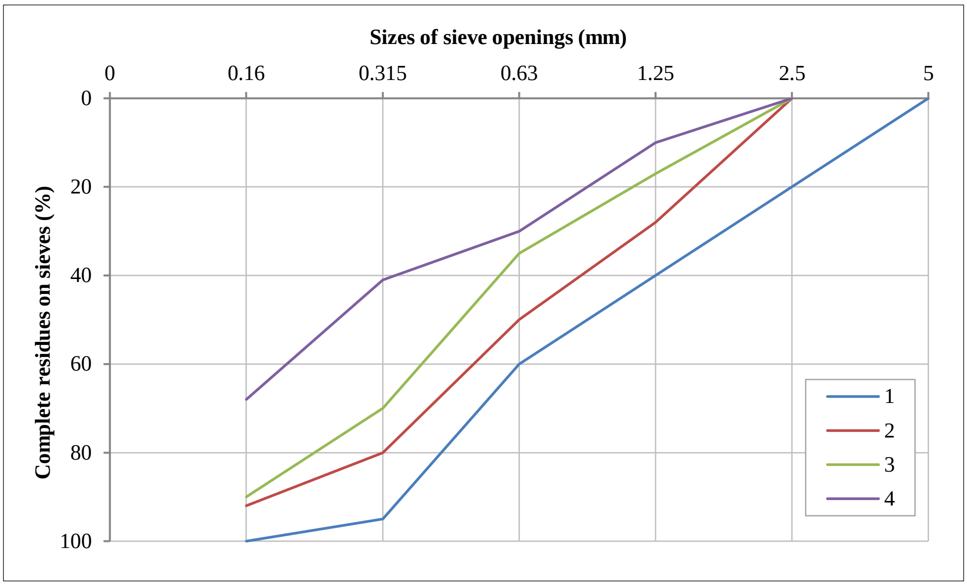


Figure 8. Screening curve of crushed natural sands with Mк = 3.15, Grinding duration, min: 1 – 0; 2 – 10; 3 – 20; 4 – 30

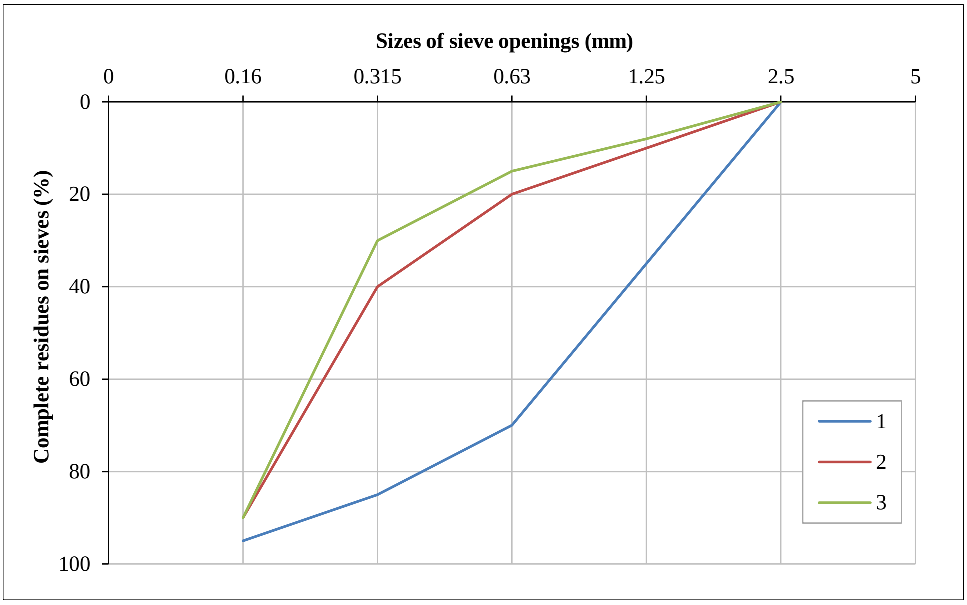


Figure 9. Sifting curve of crushed quartz sands with Mк = 2.93, Grinding duration, min: 1 – 0; 2 – 15; 3 – 30

As can be seen from the data provided, reducing the grinding time to 30 minutes allowed stabilizing the level of sand dispersion at an acceptable level. When grinding sand with Mk = 3.15 for 10, 20, and 30 minutes, the fineness modulus decreased from 2.95, 2.21, and 1.48. When grinding harder quartz sand for 15 and 30 minutes, the fineness modulus decreased from 2.93 to 1.61 and 1.44, respectively. In both cases, the sand was not overground to the level of cement dispersion, which would have inevitably led to a colloidal mixture.

The molded samples prepared for steaming in a steaming chamber and autoclave are shown in Figure 10; the test results are shown in Figures 11 and 12.

(a)

(b)

(c)

Figure 10. Molded cylindrical samples (a) and placing cube samples and cylindrical samples in a steam chamber (b) and an autoclave (c)

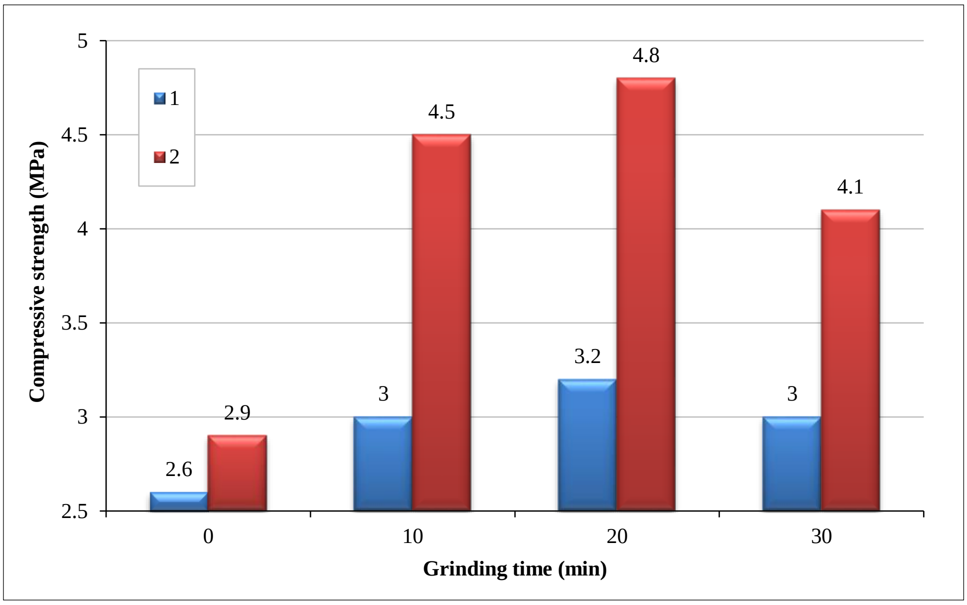


Figure 11. Effect of the duration of grinding natural sand with Mk = 3.15 on the compressive strength of foam concrete with a density of 900 kg/m^3, 1 – after steaming; 2 – after autoclave treatment

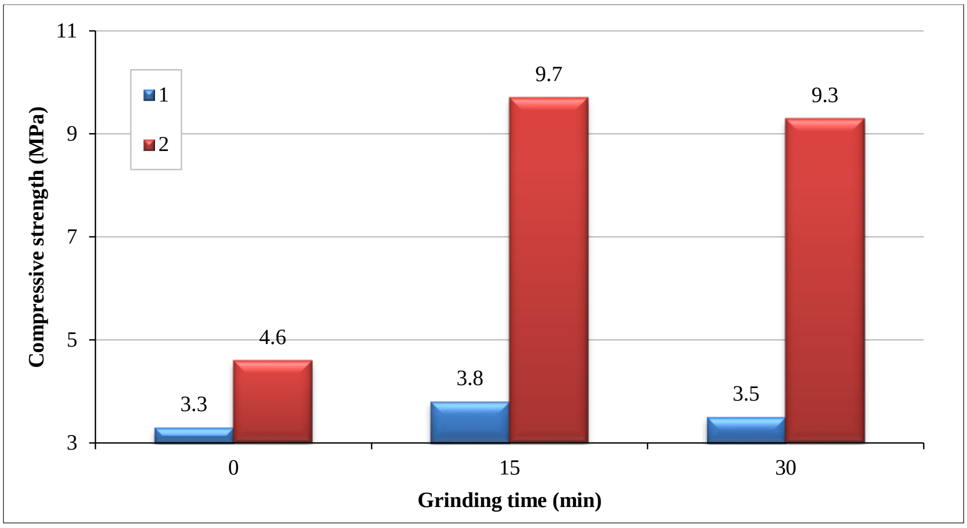


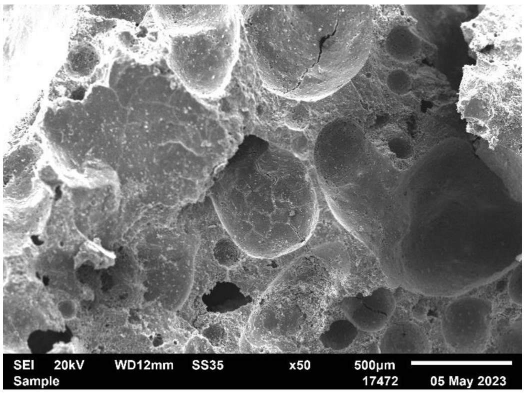
Figure 12. Effect of the duration of grinding quartz sand with Mk = 2.91 on the compressive strength of foam concrete with a density of 900 kg/m³, 1 – after steaming; 2 – after autoclave treatment

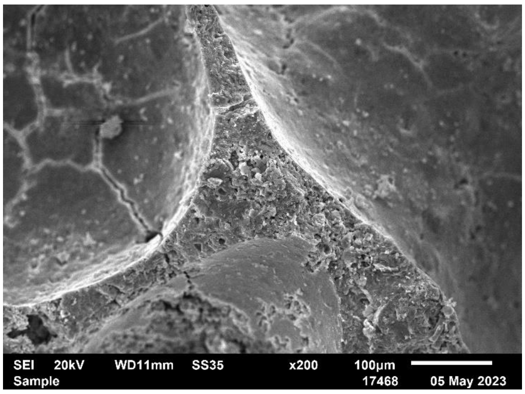
A joint examination of the data in Figures 13 to 15 and Tables 4 to 6 allows us to conclude that the quartz content and the effect of the short-term grinding process are important for the structure and strength of both non-autoclaved and, especially, autoclaved foam concrete. Thus, in the region of optimal sand dispersion (Mk <2), the compressive strength of non-autoclaved and autoclaved foam concrete on unmilled fine sand with a quartz content of 37% and Mk = 1.86 is 2.5 MPa and 3.2 MPa, respectively; on milled sand with a quartz content of 55% and Mk = 1.48, the strength is 3.2 and 4.8 MPa, respectively; on sand with a quartz content of 98.7% and Mk = 1.61, it is 3.8 and 9.7 MPa, respectively. Thus, when producing non-autoclaved cellular concrete by using quartz sand and subjected to grinding for 15 minutes compared to using unground low-quartz sand, in this case with a quartz content of 37%, a more than 1.5-fold increase in strength is achieved from 2.5 to 3.8 MPa (by 52%), and autoclaved foam concrete more than 3-fold - from 3.2 to 9.7 MPa. As expected, during autoclaved hardening of samples, the quartz content and the degree of dispersion of sand play a decisive role in the strength of autoclaved foam concrete and to a much lesser extent - non-autoclaved.

According to theoretical views, the strength of materials with a granular structure depends mainly on the number and strength of phase contacts, and the strength of the contacts in turn depends on the conditions of structure formation and hardening of cellular concrete. During autoclave treatment in a saturated water vapor environment, at a high temperature (174-200 ºC) and alkalinity of the environment (pH > 12), quartz grains partially dissolve from the surface and interact with the products of hydrolysis and hydration of cement to form low-basic hydrosilicates and calcium hydroaluminates. The latter, due to the proximity of the crystalline structures to the quartz structure, epitaxially grow together with it over the entire surface, forming a continuous surface contact. Growing quartz particles, moving in a liquid supersaturated solution of reactants, approach each other at a distance that allows simultaneous nucleation on both surfaces of the approached particles, which is accompanied by the formation of a strong crystalline intergrowth. A crystalline intergrowth between cement particles is formed in a similar manner. In the spaces between cement and sand particles, a porous condensation-crystallization structure of synthesized calcium hydrate compounds is thus formed [30, 40]. The high strength of calcium hydrosilicates, the condensation-crystallization nature of the solid phase structure, the strong intergrowth of the cement reaction products with the surface of quartz grains, the high degree of crystallization of the reaction products and phase contacts provide autoclaved cellular concrete with high strength [30, 41]. The picture of the microstructure of autoclaved foam concrete samples (Figure 13), together with the experimental data (Figure 12), is in good agreement with the above-mentioned theoretical principles of the hydration mechanism of cellular concrete during autoclave treatment.

A somewhat different picture is observed when studying the results of tests of twin samples hardened in a steam chamber. The quartz content in the sand has a significantly smaller effect on the formation of the strength of non-autoclaved foam concrete. During non-autoclaved hardening of cellular concrete, its solid phase is composed of smaller, weakly crystallized calcium hydrosilicates and has a predominantly coagulation structure. This means that the dispersed particles aggregated in the coagulation structure are separated from each other by thin layers of a dispersion medium containing in some cases, in particular in foam concrete, surfactants that create a structural and mechanical barrier for contact interaction of particles [30]. Under low temperature conditions, the solubility of quartz sand grains slows down sharply and their chemical interaction with the products of hydrolysis and hydration of cement is practically excluded, and, accordingly, the formation of a strong crystalline intergrowth. The absence of such a splice is a significant obstacle to increasing the strength of non-autoclaved cellular concrete to the level of autoclaved concrete.

The structure of non-autoclaved foam concrete at different magnifications is shown in Figure 14. At 200x magnification, it is especially clear that the solid phase of autoclaved samples has a dense structure, which indicates the fusion of cement hydrates with quartz sand, while the structure of non-autoclaved samples is characterized by a loose structure. X-ray studies of samples (Figure 15) confirm classical theoretical studies on the mechanism of the hydration process of clinker cement minerals and their interaction with quartz sand under conditions of autoclave and non-autoclave processing.





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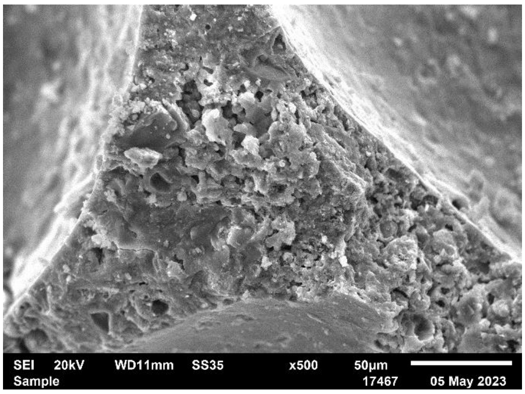
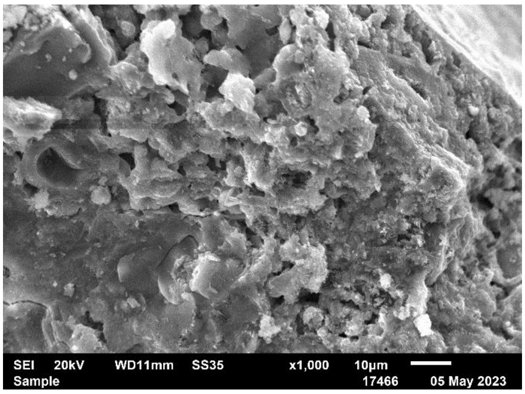
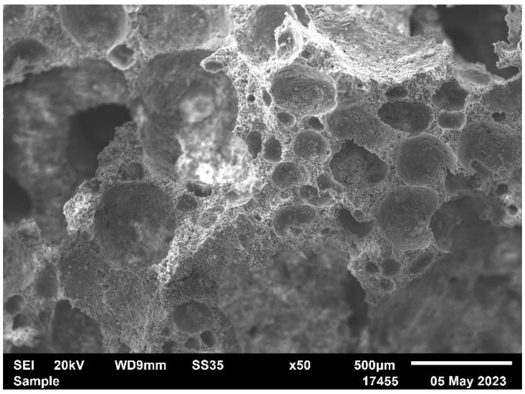
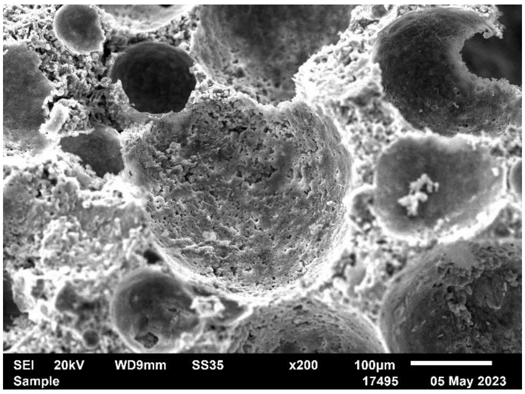




x500 x1000

Figure 13. Microstructure of autoclaved samples with ground quartz sand filler





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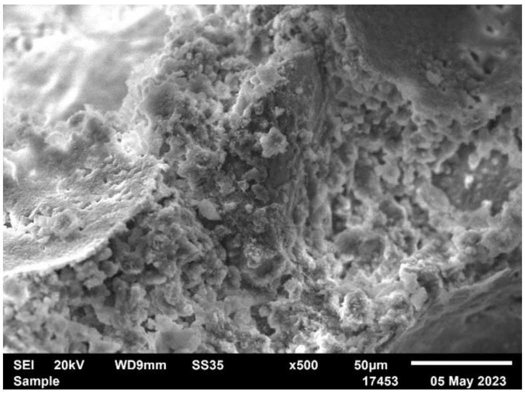

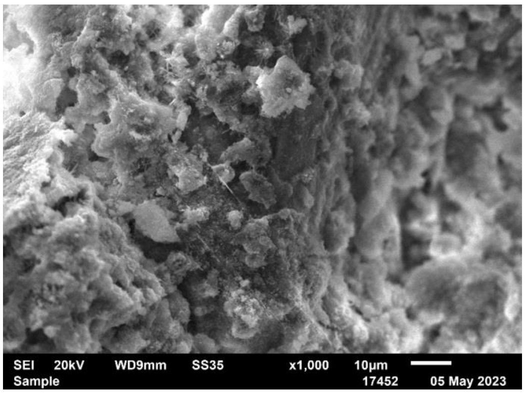

x500 x1000

Figure 14. Microstructure of samples with ground quartz sand filler that underwent heat treatment in a steam chamber

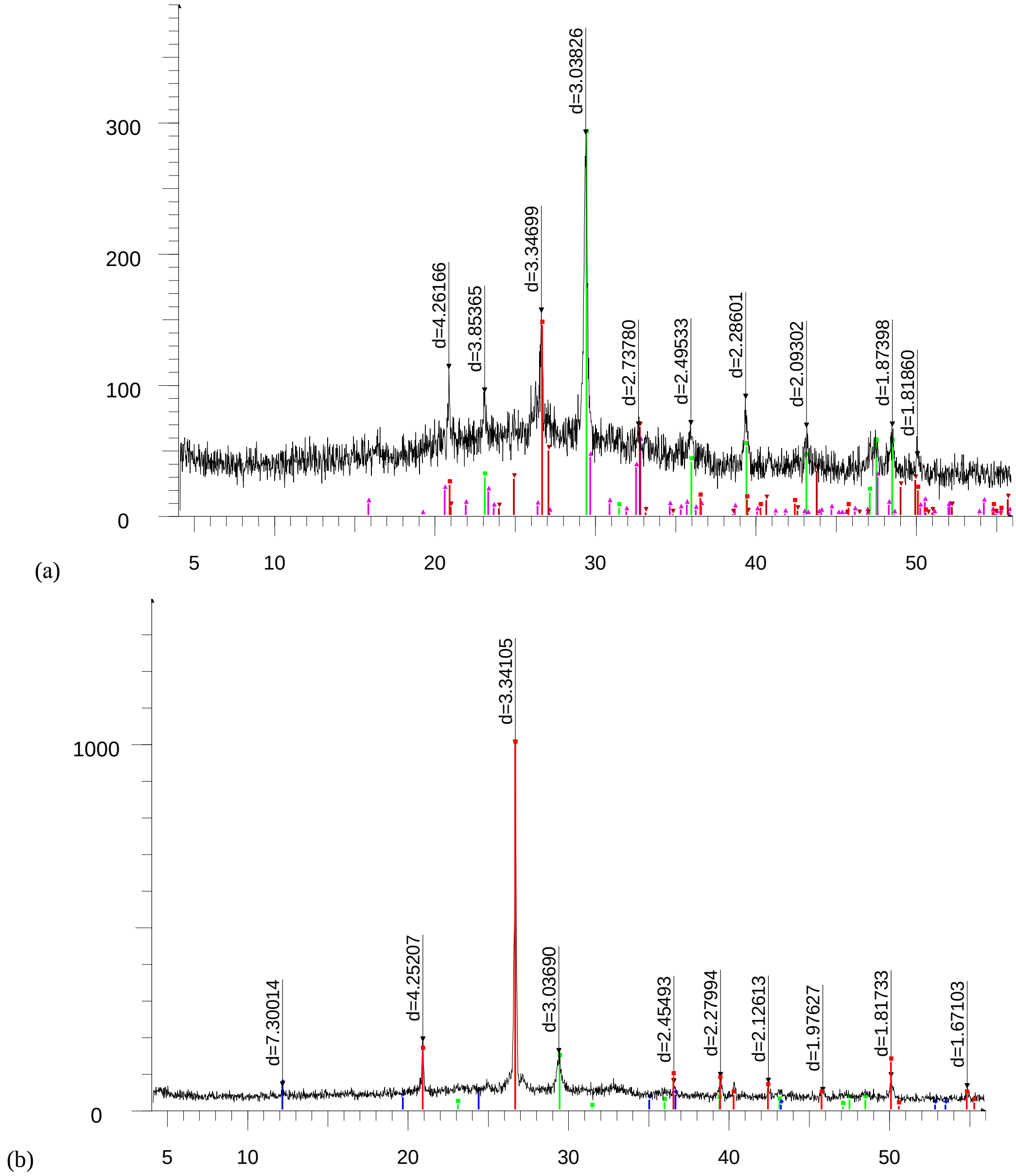

Figure 15. X-ray diffraction patterns of foam concrete on quartz sand, ground for 15 minutes, after heat treatment (a) after heat treatment in a steam chamber; (b) after autoclave treatment

The strength of non-autoclaved foam concrete with a density of 900 kg/m^3 increased from 3.3 to 3.8 (on quartz sand). The increase in the strength of autoclaved foam concrete was 6.3 versus 9.7 MPa. At elevated temperature and saturated steam pressure, tricalcium (C3S) and dicalcium (C2S) calcium silicates, as well as other minerals, interact with silica, resulting in the formation of additional calcium hydrosilicates instead of free calcium oxide hydrate obtained during the hydrolysis of C3S, and more stable and stronger low-basic calcium hydrosilicates of the CSH (B) type with the general formula xCaO·SiO2·nH2O, where x is in the range of 0.8-1.5, are obtained instead of dicalcium hydrosilicate formed during the hydration of C2S. During autoclave treatment, calcium aluminates and aluminoferrites interact with ground quartz sand, forming very strong and durable crystals of hydrogarnets, characterized in general by the formula 3CaO·Al2O3·xSiO2·nH2O.

During heat treatment of concrete with saturated steam at atmospheric pressure, the process of interaction between calcium hydroxide and silica is practically not observed. Tri- and di-calcium calcium silicates form hydrosilicates which show three diffraction lines [42]. One of them is the strongest and widest band with a maximum at 3.04-3.05 A° and two are significantly narrower lines at about 2.79 and 1.82 A°. These lines are consistent with the strongest lines of tobermorite [42].

At the same time, the following should be noted. Experimental data have shown that the maximum strength of D900 grade foam concrete based on non-quartz sand, achieved during heat treatment in a steam chamber, is 3.2 MPa, with samples measuring 7.07×7.07×7.07 cm, which, converted to grade strength according to GOST 12852.1-77 [43], is 22.4 kg/cm2. This strength value is insufficient for panels used as partitions in multi-story residential buildings. According to the recommendations of KazNIISSA, the strength class of lightweight concrete for non-load-bearing walls in seismic zones should be at least B2.5 (32.74 kg/cm^2). In order to increase the strength of foam concrete, experimental studies were conducted with a nano-additive - sol-gel liquid glass. Analysis of scientific and technical literature shows the effectiveness of the sol-gel when introduced into concrete systems [44-46].

The additive was introduced in the amount of 0.2-1% of the cement mass. Natural sand activated for 20 minutes in a ball mill was used as a filler. The volume of the mixture was prepared based on obtaining 2.5 liters of molding mass. Samples were molded with dimensions of 7.07x7.07x7.07 cm in the amount of 6 pieces. Three samples were steamed, three samples were kept for 28 days in a hydraulic bath. Before testing, the samples were dried at 105 ºC until a constant mass was achieved.

The compositions of the prepared samples, calculated per 1 liter, and the properties of the tested samples are presented in Tables 7 and 8.

Table 7. Compositions of foam concrete samples with the addition of sol-gel liquid glass

Name of components	Composition			
	1	2	3	4
Portland cement M500, g	415	415	415	415
natural sand with Mk = 3.15, g	415	415	415	415
sol-gel liquid glass, g	0	0.8	2.9	4.1
water, ml	250	250	250	250
foam, l	0.55	0.55	0.55	0.55

Table 8. Physical and mechanical properties of foam concrete with the addition of sol-gel liquid glass

Indicators	Composition			
	1	2	3	4
dry density. kg/m^3	895	900	910	905
compressive strength. MPa. after steaming	3.2	3.5	4.2	4.1
compressive strength. MPa. after 28 days of hardening	3.8	4.0	5.1	4.9
conversion to grade strength*. kg/cm^2	26.6	28.0	35.7	34.3
foam concrete grade	M25	M25	M35	M35
foam concrete class by compressive strength	B1.5	B1.5	B2.5	B2.5

* According to GOST 12852.1-77 (Cellular concrete. Test methods)

The obtained data show that the use of sol-gel liquid glass in small doses allows to increase the strength of steamed foam concrete by 31.2%, hardened for 28 days - by 34.2%. At the same time, the concrete compressive strength class B2.5 is ensured.

4. Conclusion

One of the promising areas of application of non-autoclaved foam concrete is the production of panels for partitions, mounted manually in multi-storey frame buildings. In this case, the most optimal is the use of foam concrete with a density of 900 kg/m^3, which provides the most favorable combination of mass and sound insulation of the panel. Panels are manufactured with the following dimensions: length 280-320 mm (for the height of the room), width 600 mm and thickness 100 mm. The mass of such a panel is 150-170 kg, which allows it to be mounted by two workers using low-mechanization equipment.

When producing non-autoclaved foam concrete, it is not necessary to use quartz sand. It is possible to use ordinary natural feldspar sand with a fineness modulus from 1.43 to 2.45, in which the quartz content is less than the values specified by standards. The best results are achieved by using coarse sand with Mk>3 subjected to short-term grinding until the fineness modulus is reduced to the recommended values. The grinding duration must be determined empirically, since the rate of change in sand dispersion depends on its mineralogical composition and the diameter of the mill.

Foam concrete D900 grade M35 of non-autoclaved hardening cannot be obtained using only cement, sand and foaming agent. To achieve the desired strength, it is necessary to additionally use chemical additives, in particular sol-gel liquid glass.

High strength of cellular concrete is achieved only with the formation of a chemical bond between the products of hydrolysis and hydration of cement with grains of quartz sand, the conditions for which are created during autoclave treatment. During non-autoclave treatment, a predominantly coagulation bond is formed between the binder and the filler, which does not predetermine the receipt of a dense structure.

5. Declarations

5.1. Author Contributions

Conceptualization, M.S., V.L., and B.K..; methodology, M.S., V.L., and G.T.; investigation, M.S. and E.K.; writing—original draft preparation, M.S. and E.K.; writing—review and editing, V.L., Y.S., and G.N. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are contained within the article.

5.3. Funding

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5.4. Conflicts of Interest

The authors declare no conflict of interest.

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